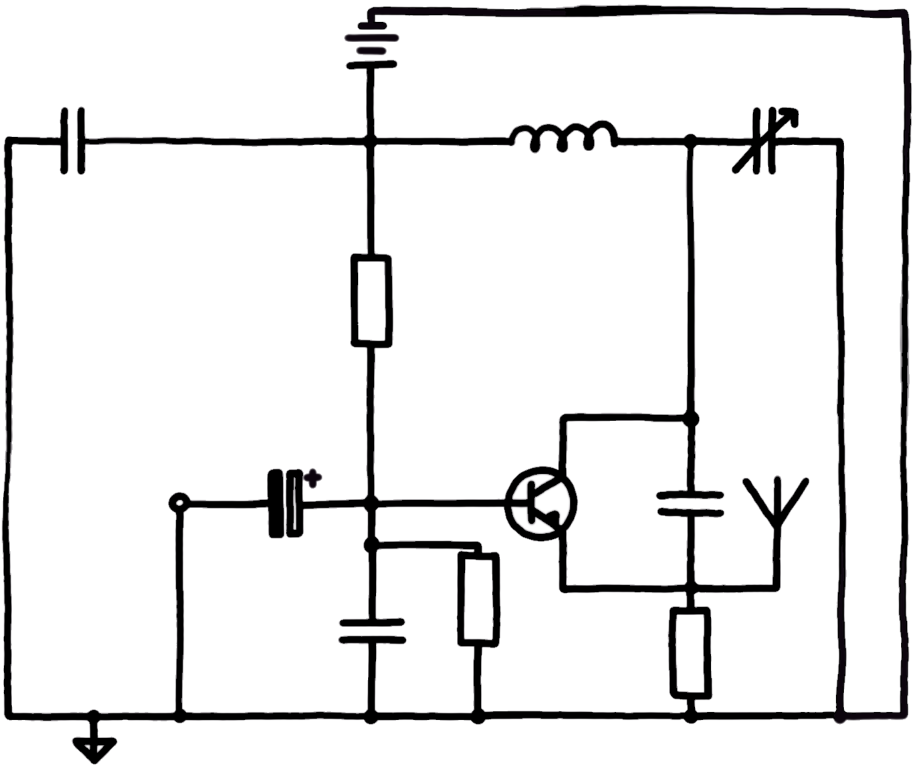
Build Your Own Mini FM Transmitter



other networks for everyone

by libi rose striegl (KR0SES) & Lori Emerson (KF0LCB)

Build Your Own Mini FM Transmitter

OTHER NETWORKS FOR EVERYONE #1

www.othernetworks.net

by libi rose striegl (KROSES) & Lori Emerson (KF0LCB)

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0.0 introduction

0.1 What are Other Networks and Why Do We Need Them?

It is no longer debatable: the network we call "the internet" is not the network we want nor the network we deserve. Over the past thirty years or so, the Web has unquestionably devolved into the only network most of us know about and therefore it's also one that most of us accept will ruthlessly track, surveil, and, in Cory Doctorow's words, increasingly become a place of "enshittification." The Web is also now one of many networks--including Bluetooth, Wi-Fi, and cellular--we have little to no sense of how it works. How many everyday users know that the Web is only one of many networks that make up an internet we call "the internet"? Or, how many know that radio is integral to nearly every network we use? How many even know how radio waves work?

“Other Networks," then, is a cluster of projects I have been working on for some years, often in collaboration with the irreplaceable libi striegl, to uncover, document, archive, and experiment with networks that existed before the internet or networks that currently exist outside of this internet. The goal of these projects is not only to significantly expand the historical record. The goal is also to make this knowledge about other networks accessible so that we may begin to reimagine what might be possible in the future. What networks can we bring back to life? What networks can we create? What networks are sustainable over the long term?

What networks can exist within a non-commercial, cooperative context?

In this spirit of accessibility, especially for those with no background whatsoever in electronics or radio, this pamphlet is the first of many to come in a series we call "Other Networks For Everyone." While there are many possible iterations of other networks that are relatively easy to build, we have become increasingly convinced that we haven't yet begun to tap the potential of amateur radio. Since its inception in the early 20th century, nearly all of the discourse in and around amateur radio has been dominated by a forbidding aura of expertise that seems intent on making radio as mysterious and as inaccessible as possible. One could easily say that a radio priesthood laid the groundwork for what Byte magazine called in 1976 the "software priesthood"--a movement in computing that encouraged users to stop opening up their machines to understand how they work and instead treat them as if they're simple, household appliances that one need not understand.

0.2 Micro-Broadcasting as an Other Network

Coincidentally or not, at the same time as this "software priesthood" emerged in the 1970s, a movement began in Europe toward experimenting with micro-broadcasting. 'Microbroadcasting' is often used interchangeably with 'micro-radio,' 'miniFM', and sometimes even 'free radio'. These are a collection of practices involving the use of a low power transmitter (either as an aesthetic or political choice or out of necessity) over a limited distance and thus reaching a limited

number of people. It is also considered a type of "community media" because of its local and non-commercial nature. Given the low power (as much as 100 watts but often as low as 1 watt) and short distances involved (as much as five kilometers from the transmitter but often much shorter), microbroadcasting can be both unlicensed and legal. However, regulations determining the legal status and power of micro-broadcasting vary significantly over time and from country to country; if national regulatory bodies prohibit individuals from transmitting to their local community, microbroadcasting may turn into pirate radio.

The fact that regulatory bodies determine whether and how micro-broadcasting is legal means it is not a practice determined strictly by the constraints of one's transmitter. Rather, as Tetsuo Kogawa writes in "A Micro Radio Manifesto," "micro means diverse, multiple, and polymorphous. If micro does not mean small in physical size, then even physically bigger radio station [sic] could become micro. Micro radio is an alternative to mass medium and global communications that could cover the globe with the qualitatively same and patterned information." Microbroadcasting is therefore primarily a social practice aimed at providing diverse points of view while also resisting the commodification of these points of view and thus its origins can be traced to specific forms of media activism rather than, for example, early wireless radio experiments with low power over short distances.

Based in Bologna, Italy, and lasting from 1976 to 1981, the

unlicensed radio station Radio Alice was likely the first instance of microbroadcasting as defined above. Even though it was referred to as "free radio" and pre-dated the emergence of the term "microbroadcasting," its main founders (students/activists Franco "Bifo" Berardi, Maurizio Torrealta, Filippo Scòzzari, Paolo Ricci, and Carlo Rovelli) essentially envisioned Radio Alice as a conscious micro radio experiment that sought to distribute control of the airwaves across many small transmitters as a way to flatten hierarchies between sender and receiver, embrace localism, and use art to unsettle if not unseat capitalism. As the editors of the Toronto-based magazine The Red Menace described it in 1978, "Radio Alice broadcast news of the events as they occurred, often by airing telephone calls from militants who described events, called for assistance in a given sector, and reported police movements. The station was twice raided and closed down by police, but resumed broadcasting by switching locations and resorting to a transmitter powered by a car battery."

A few years later, in the early 1980s, Tetsuo Kogawa introduced free radio to Japan, calling it "miniFM" as he led the way to hand-building tiny FM transmitters that used less than a hundred milliwatts and only had a half mile radius. The term "micro-radio" or "micro-broadcasting" then emerged in the U.S. in 1983 in the wake of the police beating African American Dwayne Readus, who later changed his name to Mbanna Kantako, in a public housing development in Springfield, Illinois. Kantako first created the Tenants Rights Association (TRA) and, to make sure the TRA could reach as

many residents of the development as possible, he also created radio station WTRA using a one watt transmitter and broadcast from his living room. In 1988, WTRA became Zoom Black Magic Liberation Radio then Black Liberation Radio followed by Human Rights Radio.

0.3 Simplifying "the simplest radio broadcaster"

As we learned more about micro-broadcasting and the untapped potential of amateur radio, we eventually realized that, if we wanted to begin the slow, arduous work of getting others involved in probing the limits and possibilities of radio, we needed to get licenses ourselves. We then spent several months attending an online class aimed at increasing the number of women and people of color with amateur radio licenses--a class which we appreciated but which we found was still unwittingly geared to those with an engineering background. After receiving our licenses in January 2023, we resolved to teach classes and workshops for anyone outside of engineering in a way that explained electronics and radio from the ground up and that, ideally, made it easier to get licensed.

Fortuitously, we had the opportunity to test run a radio workshop in May 2023 when Darren Wershler invited us to help teach a graduate seminar at Concordia University (Montreal, Canada) on maintenance, repair, and sustainability. The class met on Zoom for a week to discuss readings and we then met in person for a week to work on projects related to the theme of the class. libi and I volunteered to lead a project to give students the opportunity to build mini FM

transmitters by following Tetsuo Kogawa's instructions for "the simplest radio transmitter." What we discovered, however, was that the instructions were far from simple, especially for those who had no experience with electronics. Some of the problems that students encountered: the instructions did not include a schematic so much as they included a diagram that contradicted itself in places; the original circuit was for a transistor that is not readily available outside of Japan and the instructions for an alternative transistor were confusing; there were inconsistent values on resistors and capacitors and no clear instruction on how to determine appropriate substitutions; and, finally, it was not clear that the copper plates in the design needed to be insulated from each other, causing a short in the circuit.

Once libi and I returned home, we spent the next six months crafting a new set of instructions for building a mini FM transmitter that builds on Kogawa's instructions and is even more clear, thorough, and accessible. libi did most of the writing, photographing, layout, and design and my role was to let libi know every time anything in the instructions was unclear and to suggest different wording. It was a painstakingly slow and incredibly rewarding collaborative process for us both. We hope this pamphlet encourages many others to feel emboldened to experiment with this powerful example of an other network that is for everyone.

–Lori Emerson, December 2023

0.4 Sources

David J. Hess and Robert Gottlieb, Localist Movements in a Global Economy: Sustainability, Justice, and Urban Development in the United States (MIT Press, 2009); Tetsuo Kogawa, "A Micro Radio Manifesto," Polymorphous Space website (2002, 2006); Marco Briziarelli, "Tripping Down the (Media) Rabbit Hole: Radio Alice and the Insurgent Socialization of Airwaves," Journal of Radio & Audio Media, 23:2 (October 2016); "Radio Alice: Radio in Action in Italy, The Red Menace 2:2 (Spring 1978); Tetsuo Kogawa, "Toward Polymorphous Radio," Daina Augaitis and Dan Lander Eds., Radio Rethink : Art Sound and Transmission (Walter Phillips Gallery, 1994); Lawrence Soley, Free Radio: Electronic Civil Disobedience (Routledge, 2018); Steven O. Shields and Robert Ogles, “Black Liberation Radio: A Case Study of Free Radio Micro-broadcasting,” Howard Journal of Communications 5 (1995); Andy Opel, Micro Radio and the FCC: Media Activism and the Struggle over Broadcast Policy (Praeger, 2004); Christina Dunbar-Hester, "Spectral Utopias: Community Radio in the United States, 1970 to Present," Historia Actual Online, 54:1 (2021); Christina Dunbar-Hester, Low Power to the People: Pirates, Protest and Politics in FM Radio Activism (MIT Press, 2014)

1.0
common electrical terms

Active Component:

An active component is any component which does not meet the definition of a passive component; it may supply, amplify, or control current within the circuit.

Alternating Current:

Abbreviated to AC, alternating current is the type of current that comes out of a wall socket. The flow of alternating current periodically reverses direction and changes its strength continuously over time. It is capable of being transmitted over great distances without dissipating, which is the primary reason for its use in the electrical grid. Many electronic devices convert alternating current into direct current for use.

Ampere:

Ampere, commonly shortened to amp, is the unit used for measuring electrical current.

Antenna:

A device for sending and receiving electromagnetic waves. An antenna of some form is necessary for any radio reception or transmission.

Anode/Cathode:

The anode is the positive terminal in a battery or power supply that electrons flow away from when a device is in use, while the cathode is the negative terminal where electrons flow towards, completing the circuit.

Breadboard/Breadboarding:

A breadboard, sometimes called a solderless breadboard, is a re-usable tool for building circuits. It is useful for constructing and testing circuits without permanently fixing components together.

Capacitance:

Capacitance is the capability of a material object or device to store electrical charge. The unit used to measure capacitance is the farad.

Conductance/Conductivity:

Conductivity represents a material's ability to conduct electrical current. It is measured in siemens per meter.

Direct Current:

Abbreviated to DC, direct current is the type of current that comes out of a battery, a rechargeable power bank, a solar panel, a USB wall plug, etc. The flow of direct current is always in the same direction and at the same strength, which is why many electronic devices convert power from AC to DC for use.

Electrical Charge:

The physical property of matter that causes it to experience a force when placed in an electromagnetic field. Electrical charge can be positive, negative or neutral, generally determined by the balance of protons and electrons at an atomic level. Positive charges repel positive charges, negative charges repel negative charges, and positive and negative charges attract each other. Neutrally charged matter does not experience force in an electromagnetic field.

Electrical Circuit:

Generally shortened to circuit, an electrical circuit is a network of electrical components in a closed loop wherein current has a return path to the power source. In a circuit like the one we build here, where electrical power is supplied by a battery, the current travels out from the positive side, through the components in the circuit, and back to the battery via the negative side.

Electrical Component:

An electrical component is a general term for any part of an electrical circuit. Components are often described as "through-hole" or "surface mount", which refers to their construction and to the way they are attached to a printed circuit board (PCB). Through-hole components have legs or leads; they are attached to a PCB by putting those legs or leads through the metal-ringed holes and soldering them in from the other side. Surface mount components are placed on metal pads on the PCB and soldered down from the same side, often by heating the solder using an oven instead of a soldering iron.

Electrical Conductor:

A conductor is an object or type of material that allows the flow of electrical current in one or more directions. Metals are common conductors, such as the copper or aluminum used to make most wires. Water, unless it is absolutely free of any impurities like dissolved salts or metals, is also a conductor. Because organisms have bodies that are largely water-based, the bodies of plants and animals (humans included) conduct electricity to some extent. This is why it is important to protect

yourself from direct contact with anything carrying high voltage, like power lines or wall power outlets.

Electrical Current:

An electrical current is a flow of charged particles moving through electrical conductors or space. In the case of a circuit like the one we build here, the electrical conductors are the metals that make up the wires and other components. The charged particles are electrons. The unit used to measure the current is the ampere (generally shortened to "amp").

Electrical Insulator:

An electrical insulator is a material in which electrical current does not flow freely. Insulators can be described as having very high resistance. Common insulators include ceramics, rubbers, plastics, paper, and glass. The deployment of these materials depends on many factors, including how much heat may be generated as a by-product of an electrical circuit. For example, while paper was once used as an insulator for electrical wiring in houses, paper is highly combustible and so while it resists electrical current it does not resist fire and can combust because of the heat generated as electricity flows through wires.

Electrical Energy:

Electrical energy is electrical potential put to use. It describes the forces that act on electrically-charged particles and the subsequent movement of those particles, often though not always in the form of electrons moving through wires. Electrical energy may be converted from electrical potential (voltage) into heat, physical motion, sound, light, radiation, etc.

Electromagnetism:

Electromagnetism combines two fundamental forces: electricity and magnetism. Electricity involves tiny particles called electrons carrying electrical charge, which in turn powers devices, lights, and motors. Magnetism is the force that makes magnets attract or repel each other due to their magnetic fields. When electrons move while carrying electrical charges, they create magnetic fields. This connection between electricity and magnetism is what we call electromagnetism.

Electromagnetic Field:

An electromagnetic field is an invisible area around either electrical charges or magnets. Within that area, electrically charged particles or magnets can affect other objects without touching them. Whenever electrically charged particles move or whenever magnets are in action, a field is created. This field is responsible both for making magnets attract or repel each other and for transferring electrical energy. The transfer of electrical energy is particularly important because it allows us to use electricity to power devices.

Electromagnetic Wave:

An electromagnetic wave is a type of energy that travels through space. As such, electromagnetic waves can move without wires or other conductive materials. These waves are made up of two key parts: electrical and magnetic fields. When these fields interact and change, they create waves which can be used to carry energy that can be encoded as information. These waves exist naturally, for example as light from the sun. They can also be generated for various

purposes including radio waves used for communication, microwave ovens, and X-rays.

Electromotive Force:

Electromotive force (emf) is the energy that is transferred to a circuit, measured in volts. Emf can be produced through conversion from one type of energy to another, i.e. from chemical energy to electrical energy as with batteries, from mechanical energy to electrical energy as with wind turbines, or from light to electrical energy as with solar panels.

Electron:

An electron is a type of elementary particle, and these particles make up everything around us. Electrons carry an electrical charge. When these charges move around inside conductive materials such as metals, they allow us to create and harness electricity. When these charges stay in place, they form the outer layer of atoms.

Energy:

Energy is any property that could produce a change when transferred to a physical system. We can often recognize the expenditure of energy in physical movement, heat, and/or light. While here we are generally talking about electrical energy generated by chemical reactions inside of batteries and radiant energy from electromagnetic circuits, there are many other forms including kinetic, potential, elastic, etc. All living organisms constantly take in and release energy. The unit used for measuring energy is the joule.

Force:

In physics, a force is an influence that can cause any object to change its velocity unless it is counteracted by other forces. In this definition of force, objects may be large like a vehicle or a planet or they may be invisible like a molecule or an atom.

Ground/Earth:

Ground or earth for our purposes refers to the common return path for electrical current back to the power supply. All of the components in a circuit have some connection to that return path, either directly or through another component. Ground can also mean the point at which voltages in a circuit are measured, or a direct electrical connection to the planet Earth. For example, if you plug something into a wall outlet using a 3-prong plug, if the house is properly wired that third prong will have a direct electrical connection to the Earth. This helps to prevent shock and electrical shorting. If you use a 2-prong plug, you have only connected to the common electrical return path for the house.

Joule:

The joule is the unit for measuring energy. A joule can be calculated in many ways because energy is a broad concept. For electrical energy, a joule is the amount of work required to produce one watt of power for one second.

Leg/Lead:

Leg and Lead are colloquial terms used interchangeably to indicate the wires or thin metal strips that are part of many electrical components and are used to connect those

components to each other or to circuit boards in the process of circuit building. These are more formally known as "terminals".

Load:

Load is the colloquial term for power consumption of a particular circuit or component, measured in amps and volts. If a component consumes either more volts or more amps than a power supply is capable of providing to a circuit, the component may not function properly or at all, or may damage itself, the other components in the circuit, or the power supply.

Ohm:

The ohm is the unit of electrical resistance. One ohm is the electrical resistance between two points on a conductive material when one volt of power is applied to those points and a current of one ampere is produced in the conductive material.

Open Circuit:

An open circuit is an incomplete electrical circuit, with no pathway between the terminals of the power source. An electrical project that does not work at all is often found to have an open circuit due to improper connections between components or wires that are not secured properly.

Pad:

Pad is a colloquial term used to indicate a flat metal surface on a PCB, or a pool of solder on a larger metal surface, and that serves as a place to attach electrical components. These are more formally known as "terminals".

Passive Component:

A passive component is a part in a circuit that consumes energy but does not produce it.

PCB:

Short for printed circuit board, a PCB is a layered substrate of copper and insulating materials used to connect electronic components to one another in a controlled manner. Rather than directly connecting components to each other, the PCB has metal-ringed holes and/or metal pads; these are connected internally by lines of copper that transmit current from one component to the next per the requirements of the circuit.

Pigtail:

Pigtail is a colloquial term for a plug or other electrical component that has a short length of wire already connected to it so that it's ready to connect directly to a project without any preparation.

Polarity/Polarization:

Polarity in electricity refers to the direction in which electrical current flows through a circuit or component. In a battery, charged particles exit through the positive/+ side and re-enter through the negative/- side. In a polarized component, current is only able to flow in one direction; attempting to apply current in the incorrect direction could result in damage to the component.

Positive/Negative:

Positive refers to the terminal where current is flowing out from the power source, negative refers to the terminal where

current is returning to the power source. Most of the components in a circuit will be connected to both the positive and negative terminals either directly or via the connections made with other components. Polarized components will always be connected so that their positive terminal is directed towards the positive terminal of a power supply and their negative terminal is directed towards the negative terminal of a power supply. If components are not properly connected and the current cannot pass from the power source's positive terminal through the circuit and back to the negative terminal, the circuit is either "shorted" or "open" and will not function.

Potential:

In physics, potential energy is energy held by an object because of its position relative to other objects, stresses within itself, its electrical charge, or other factors. That energy can then be released in various forms. For example, a battery holds chemical potential energy that can be released as electricity or heat, a balloon that has been rubbed on carpet holds electrical potential energy (static) that can be released as light, heat, and electricity, and a ball resting at the top of a hill holds kinetic potential energy that can be released as motion.

Power:

Power is the amount of energy transferred or converted per unit of time (measured in joules per second). Electrical power is the rate at which electrical energy is transferred by an electrical circuit. The unit for this measurement is the watt.

Prototype:

A prototype is a temporary or experimental construction of a circuit, machine, piece of software, etc. Prototypes can range from very rough to quite polished, but they are always a work in progress rather than a final version.

Resistance/Resistivity:

Resistance is the measure of a material's ability to resist an electrical current. A low-resistance material is generally a good conductor; a high resistance material could be a good insulator. Resistance is measured in ohms.

Semiconductor:

Semiconductors are materials like silicon or germanium whose conductivity is neither extremely resistive (like insulators such as glass) nor extremely conductive (like conductors such as copper or aluminum), and whose conductivity can be altered and controlled through chemical and physical adjustments. They are used in transistors and diodes, and depending on their properties they can be used to amplify and control power (like transistors), emit light (like LEDs or light emitting diodes), absorb or emit heat, etc. Semiconductor materials do occur naturally; however, most of the ones used in electronics are manufactured through various industrial processes.

Short Circuit:

A short circuit is an electrical circuit where the current travels along an unintended path with no or very low electrical impedance. Shorting can result in excessive current flowing through the circuit. The consequences can be minor, like a circuit not working at all or a component failing; or major, like

overheating, fire, and electrical shock. An example of a short circuit is when tree branches touch power transmission lines, allowing current to travel to the ground and often causing arcing, fires and power outages.

Siemens:

A siemens is a unit of electrical conductance, expressed as a ratio. One siemens is equal to one ampere per volt.

SI Units:

The international system of units, or Système International, is the modernized metric system. SI is a standardized system of units of measurement centered around seven basic units; it is also a system of recognized prefixes, abbreviations, and derived units. The seven units are the second for time, the meter for length, the kilogram for mass or weight, the ampere for electrical current, the kelvin for temperature, the mole for the amount of substance, and the candela for intensity of light. SI was initially established in 1960 by the General Conference on Weights and Measures and that body is responsible for continued updates and clarifications. It is used by most countries and in most scientific, technological and engineering fields. Most units expressed in this text are SI units; non-SI units will be noted.

Terminal:

A terminal in electronics is the point at which a conductor or component comes to an end and may be connected to another conductor or component as needed. Pad, leg, and lead are some colloquial terms for types of terminal.

Volt:

A volt is the unit of electrical potential. One volt is equal to the difference in electrical potential between two points on a conductor when the current is at a constant of one ampere and the dissipated power is one watt.

Watt:

The watt is the unit for measuring electrical power. It indicates an electrical energy transfer rate of one joule per second.

Work:

In physics, work refers to the effort or energy transferred when a force acts on an object and causes that object to move. That energy transfer is quantified in joules. It can indicate large energy transfers like the work of lifting a heavy box or pushing a car, or small energy transfers like the work of an electrical charge moving through a conductive material.

2.0 unit symbols and abbreviations

A:

Ampere or amp. The unit used to measure electrical current.

AWG:

American Wire Gauge. A scale used to denote the diameter of wire in the United States. Can be confusing as the larger in diameter a wire is, the smaller the AWG number. Commonly encountered in, for example, ear piercing gauges. Outside the United States, international standard simply measures diameter in millimeters. AWG is not an SI unit.

Ω:

Ohm, the unit used to measure electrical resistance. kΩ indicates kilo Ohm, meaning that a resistor labeled as 10 kΩ is equal to 10,000 Ω.

F:

Farad, the unit used to measure electrical capacitance. This symbol is often seen paired with additional symbols, like mF, μF, nF and pF, which indicate the metric prefixes for numbers smaller than 1.

> **m:** milli, or thousandth. mF indicates millifarad, or 0.001 farad (3 decimal places to the left of 1).

μ: micro, or millionth. μF indicates microfarad, or 0.000001 farad (6 decimal places to the left of 1).

n: nano, or billionth. nF indicates nanofarad, or 0.000000001 farad (9 decimal places left of 1).

p: pico, or trillionth. pF indicates picofarad, or 0.000000000001 farad (12 decimal places left of 1).

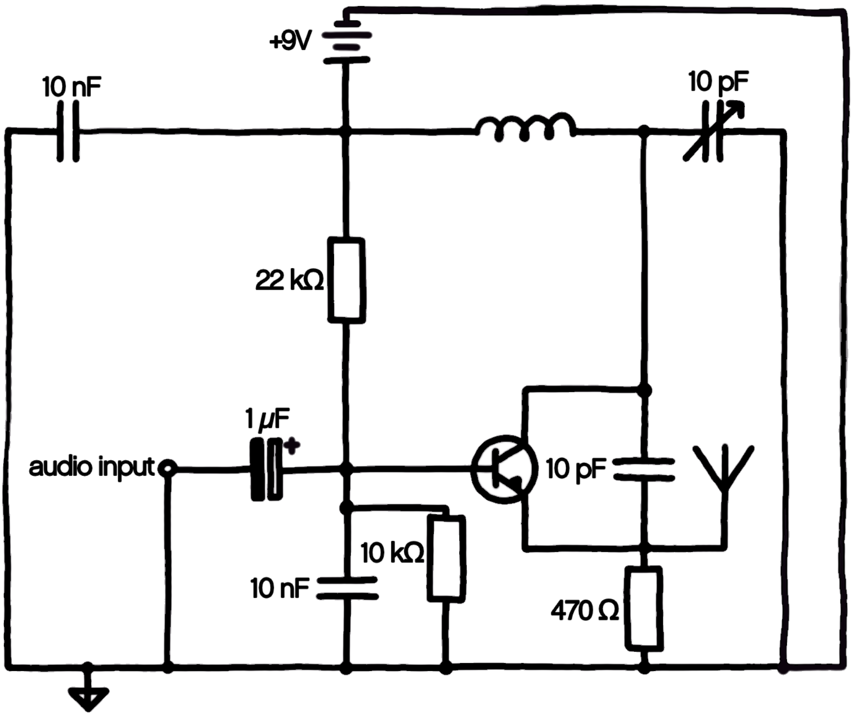
V:

Volt, the unit used to measure electrical potential. Commonly used to talk about a battery's "size", or how much energy it holds; for example, 1.5v batteries are commonly used in remote controls and 12v batteries are commonly used in cars.

W:

Watt, the unit used to indicate the rate of energy transfer. Commonly used to talk about a light bulb's energy usage or a solar panel's power rating; for example a 40 watt bulb or a 400 watt solar panel.

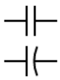
3.0
circuit diagram



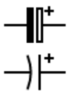
3.1 Circuit Diagram Symbols

Antenna

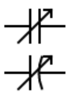
Battery



Capacitor (where two symbols are indicated, either symbol may be used)



Capacitor, polarized; the small plus symbol indicates the direction of polarity



Capacitor, variable

Coil or Inductor

Ground

Input

Resistor

Transistor (NPN)

4.0
materials

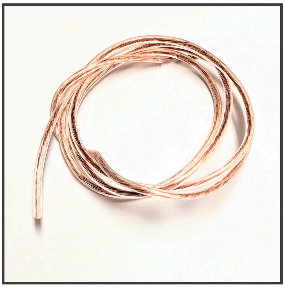
4.1 Components

- 1 radio coil (appx. 4"/10cm length 24 AWG [.5mm] enameled copper wire)
- 1 antenna (1.5'/50cm length speaker wire or other insulated wire, between 22 and 16 AWG)
- 1 audio input (3.5mm TRS plug pigtail; preferably mono)
- 1 9V battery connector
- 1 piece copper clad board
  (between 2" x 3"/5cm x 7cm and 4" x 6"/10cm x 14cm) <u>OR</u>
  1 breadboard & jumper wires
- 1 BC337 transistor
  (BC337 is a common transistor and can be bought individually or found in most transistor kits; however, if you are unable to find a BC337 transistor, you can use references such as alltransistors.com to search for equivalents.)
- 1 10 kΩ resistor
  (see color band guide referenced in the “Component Descriptions” section to identify these resistors)
- 1 22 kΩ resistor
- 1 470 Ω resistor
- 2 10nF ceramic capacitors
  (usually marked with "103")
- 1 10pF ceramic capacitor
  (usually marked with "100")
- 1 1μF electrolytic capacitor
- 1 ~10-20pF variable capacitor

4.2 Component Descriptions

Antenna

An antenna can be as simple as a length of wire and as complex as a multi-story radio tower. For our purposes, we'll be using a short length of wire. It acts as the interface between electromagnetic waves (radio waves) moving in space and electrical currents moving in circuits. In transmission, a radio transmitter generates an electrical current and supplies it to the antenna's terminals, and the antenna radiates the energy from that current in the form of electromagnetic waves. In reception, an antenna intercepts a radio wave in space and uses some of that wave's power to produce an electrical current at its terminals, and a radio receiver connected to that antenna can then amplify that current as sound or other signal.

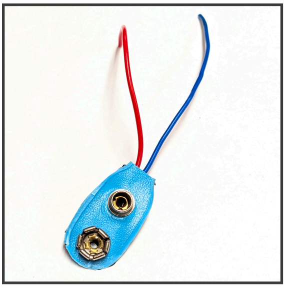


Audio Input

An audio input or audio jack is any connector meant to connect to an audio device. In this case we will be using the plug end with a Tip-Ring-Sleeve (TRS) connector. TRS connectors come in various sizes, with the 3.5 mm and 6.35 mm (1/4 inch) versions being the most common.

Battery Connector

A battery connector is a component that establishes an

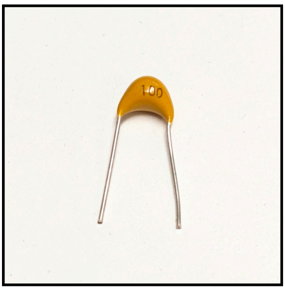


electrical connection between a battery and an electrical circuit. It typically consists of terminals or contacts that allow the flow of electrical current from the battery to the device, enabling the device to be powered or charged by the energy stored in the battery. They are available for all types and sizes of battery - we will be using one designed for standard 9 volt batteries.

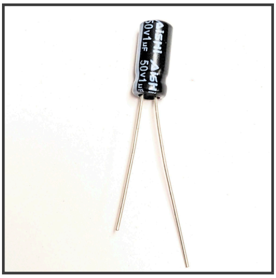
Capacitor

A capacitor stores electrical energy in an electrical field by accumulating electrical charges on two closely-set conductive surfaces that are insulated from each other by some non-conductive material. The conductive surfaces are called electrode plates and the non-conductive insulator is called the dielectric. We will be using three types of capacitor: ceramic, electrolytic, and variable.

A ceramic capacitor is a non-polarized capacitor with a



ceramic dielectric. They are the most common. The number marked on the surface denotes capacitance, generally in a common code but sometimes in a code particular to the manufacturer. The common code chart can be found online, and manufacturer specific coding will usually be included in the box if you purchase a kit.



An electrolytic capacitor is a polarized capacitor. The positive side or anode is made of a metal that forms an insulating oxide layer through a process called anodization. This oxide layer acts as the dielectric of the capacitor. A solid, liquid, or gel electrolyte covers this oxide layer, serving as the negative side or cathode of the capacitor. The capacitance of an electrolytic capacitor is printed on the side, often followed by 'v' and then another number. The number after 'v' indicates the capacitor's voltage tolerance.

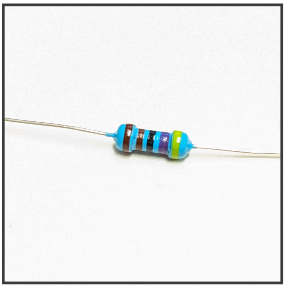
A variable capacitor is a non-polarized capacitor whose capacitance can be changed, either mechanically or electronically. They are sometimes referred to as "tuning capacitors" because they're often used to tune radios. These capacitors are not as easy to come by as the others, and generally need to be purchased individually. They come in a capacitive range, and are generally color-coded by the manufacturer.

Coil

A coil or inductor stores electrical energy in a magnetic field when electrical current flows through it. It is typically made of insulated wire wound into a coil shape or wound around a core of some kind. You will be given instructions to make a simple coil.

Resistor

A resistor is a 2-terminal non-polarized component that

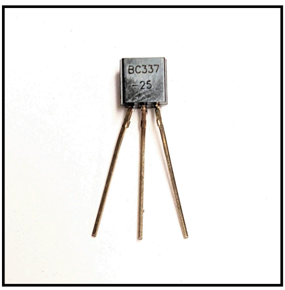


introduces electrical resistance into a circuit through its material construction. Resistors can be static, maintaining a basically stable resistance regardless of external conditions; or variable, with resistance that can be physically adjusted or that varies depending on environmental conditions such as light, heat, humidity, etc.. Light sensors, temperature sensors, volume knobs, light dimmers, etc. are all examples of variable resistors.

Static resistors are identified based on how many ohms of resistance they provide, and they are marked according to a standardized system of 4, 5 or 6 colored bands. Most static resistor packs have an identification table included in the package, and there are many online resources for identifying resistors, including this one from the electronics supplier DigiKey: www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code.

Transistor

A transistor is an active electrical component used to



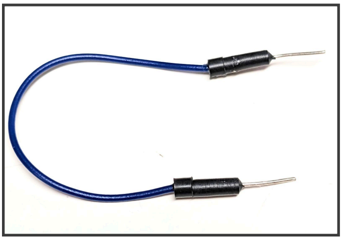
amplify or switch electrical current. Transistors are composed of semiconductor material and have at least three terminals. The terminals are known as the base/gate, emitter/source, and collector/drain. When a small electrical

current is applied to a transistor's base/gate terminal it will either emit a much stronger electrical current from one of its other terminals (amplification) OR it will allow a stronger electrical current to pass from the collector/drain terminal to the emitter/source terminal (switching).

There are two basic types of transistor (Bipolar Junction Transfer [BJT] and Field Effect Transfer [FET]), and a number of subtypes. The one we are using is a BJT transistor, and its subtype is NPN (Negative-Positive-Negative, indicating the polarity of its terminals).

Wire

A flexible strand of metal. We make reference to several types of wire: Jumper wire, solid core, and stranded core.



A jumper wire is a means for quickly and temporarily moving electrical current from one place to another. In breadboarding, it's a length of wire fitted with either a plug or a receptacle on each end and it connects different parts of the breadboard electrically. You may have used a set of jumper wires or cables to restart a car after the battery died.

Solid core wire indicates a wire that is insulated (usually in a sheath of plastic or rubber) with only a single strand of metal inside the insulation.

Stranded core indicates a wire that is similarly insulated and contains many very fine strands of metal within the insulation.

4.3 Tools

- Small coping saw OR strong kitchen shears OR craft knife (soldered version only)
- Eye protection (required for soldered version, recommended for breadboard version)
- Gorilla glue OR double-sided tape OR another adhesive suitable for metal (soldered version only)
- FM Radio (preferably with a knob-style tuning dial, but can be of any vintage)
- Sandpaper, fine-grit (required for breadboard version, optional for soldered version)
- Small screwdriver, Phillips or Pozi
- Soldering iron & solder (soldered version only)
- Tweezers OR needle nose pliers
- Wire cutter/strippers
- Standard pencil with eraser
- Magnifying glass (optional, for seeing markings on small parts)

4.4 Space Recommendations

- Flat surface with enough room to lay out all components and tools
- Adequate light
- Comfortable seating
- If soldering, good ventilation! At least an open window or an air filter (preferrably both)
- Access to electricity

5.0
skills rundown

5.1 Using Wire Cutters & Strippers

Wire strippers are used to pull the insulating material off the outside of plastic-coated wires.

If you look at yours, you'll notice a cutting edge close to the hinge, notched places marked with wire sizes in the middle (these make holes when the cutters are closed), and a gripping surface at the end.

To use, clip your wire piece a bit longer than needed, use the cutting edge to score the plastic insulation in the place where you would like to remove it, and then pull the wire through the appropriate-sized notch to slide the plastic sleeve off the end of the wire.

5.2 Breadboarding

A breadboard is a quick-connect method for prototyping circuits. We will give a brief rundown here, but there are instructional videos and texts available online if you need further guidance.

A breadboard allows for circuit prototyping and building without the need to solder the components together. Using a breadboard is a great way to test a circuit prior to soldering, or to build a circuit that you don't plan to keep.

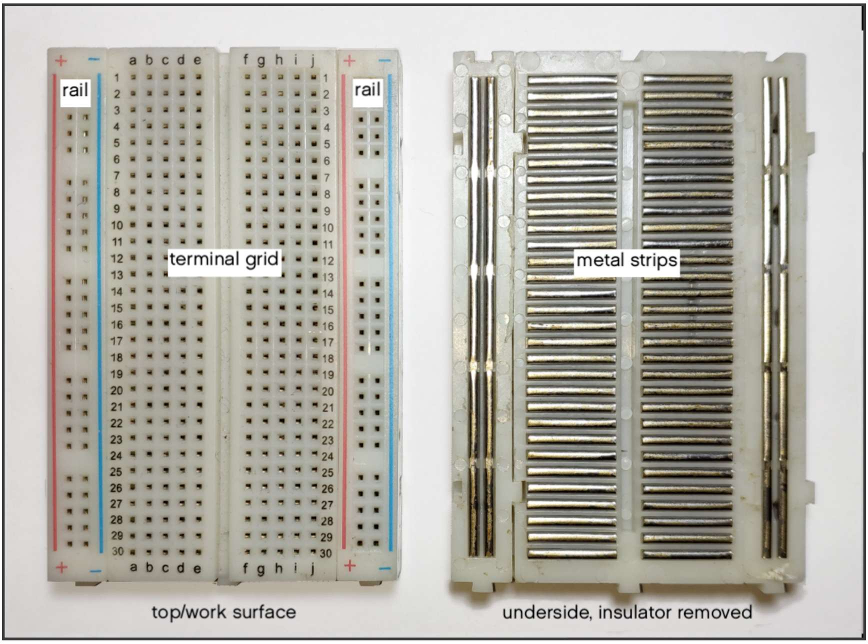
Breadboards are made of plastic with lots of little holes on one side and a layer of adhesive foam on the other, along with a hidden layer of conductive metal strips. The one pictured below is a standard orientation for breadboards. However, there are some different styles; double check the documentation for yours if it doesn't look like the one we have shown on the next page.

Oriented with the top or work surface facing up, you can see the board is divided into three areas, each of which is a separate piece of plastic. The two smaller areas, referred to as "rails", have two columns of holes and are labeled with a red "+" symbol and a blue "-" symbol as well as a red line along one column of holes and a blue line along the other column of holes. The rails are generally used to supply power to the breadboard, so the red and blue markings indicate positive and negative power connections.

The rails are located on either side of a larger central area with a distinct channel down the middle and a grid of holes that

is labeled with letters for the columns and numbers for the rows. The central piece doesn't have a consistent name, so we'll call it the terminal grid.

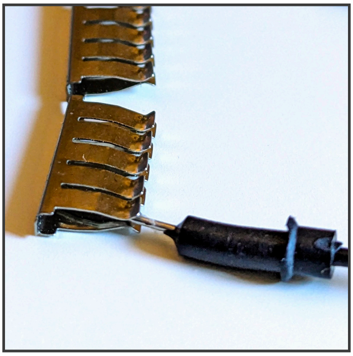
The underside is usually covered by a foam adhesive pad which holds the plastic pieces together, secures the conductive metal strips inside the plastic, and insulates the metal strips



from whatever surface the board may be placed on. The board pictured above has had the foam pad removed so that the metal strips are visible.

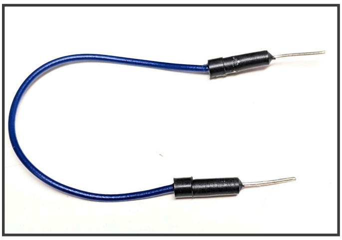
You can see on the picture of the underside that the rail pieces each have two long metal strips; these metal strips run beneath the columns of holes that are labeled with red or blue lines on the work surface. The terminal grid has two columns of horizontally oriented metal strips that run under the rows of holes on the work surface.

The metal strips have prongs that extend up into the holes on the front side of the board so that when a jumper wire or lead from an electrical component is pushed into the hole, it clips into the metal strip below and forms a reasonably secure connection, as shown below.



Pushing a lead from one component and a lead from another component into holes in the same row connects those components electrically because they are both clipped in to the same piece of metal inside the board.

The most common method for moving electricity around a breadboard is by using jumper wires like the one pictured here.



For example, if you want to electrically connect multiple rows on the breadboard, you need to use a jumper wire. You can make your own out of solid-core wire with the ends stripped off, or you can purchase pre-made sets.

5.3 Soldering

Solder is a metal alloy (a composite of multiple metals) that has a relatively low melting point. It is used as a sort of glue to bond together metal parts with a higher melting point. The solder and the parts being connected are heated together using a soldering iron, oven or torch; for our purpose you'll be using a soldering iron. The heat from the iron melts the solder which in turn fills the space between the parts. When the solder re-solidifies and the parts cool, the bond is fairly durable (though it can be broken or re-melted). The act of using solder in this way is referred to as soldering; any bond between pieces of metal created by soldering is referred to as a solder joint. When you are building electrical circuits, the solder joint allows electrical current to pass from one component to another. Soldering is also used for non-electrical purposes like plumbing and jewelry making.

As soldering involves tools that can reach dangerously high temperatures, we strongly advise at least watching video-based tutorials or, ideally, getting in-person instruction. That said, we recognize that in-person instruction can be hard to come by and varies widely depending on where you live. Places to look for in-person instruction include but are not limited to: public libraries, maker or hacker spaces, ham radio clubs, and others.

If in-person instruction is definitely not an option the electronics company Adafruit has a thorough guide to electronics soldering, including both written and video instructions, at learn.adafruit.com/adafruit-guide-excellent-soldering.

6.0
initial preparations

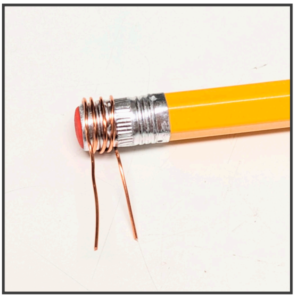
6.1 Making the coil

(This is necessary for both breadboard and soldered assembly)

Materials: Pencil, copper wire

1. Cut a roughly 4"/10cm length of 24 AWG/.5mm enamel-coated copper wire.

2. Wind the wire around the eraser end of a pencil 4 times. The grooves in the metal part of the pencil can be used to hold the wire in place and provide basic spacing for the turns of the coil.



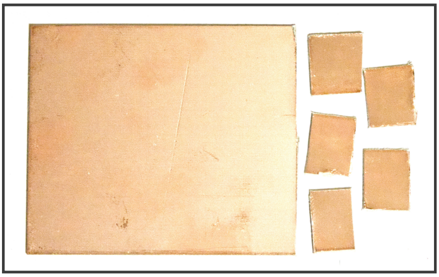
3. Take the coil off the pencil to use. Because a pencil eraser is roughly 5mm in diameter, the coil is also roughly 5mm in diameter.

4. Use fine-grit sandpaper to sand the legs of the coil up to where the turns begin, to remove the thin enamel coating on the wire.

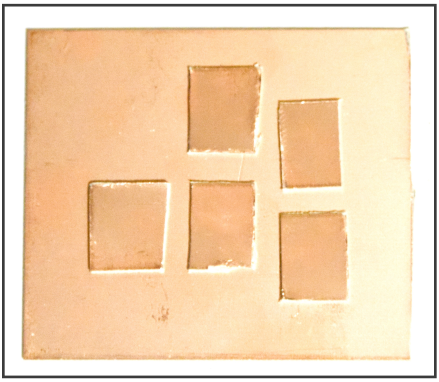
6.2 Preparing the copper board

(Skip this if you're building on a breadboard!)

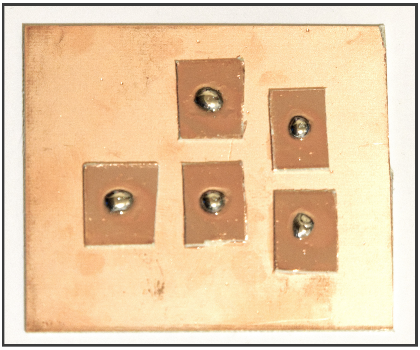
1. Wearing eye protection, cut a 1 cm/.5" strip off one end of your copper board. You can do this with a coping saw, by scoring deeply with a craft knife and snapping the board using pliers, or with tin snips/ heavy-duty scissors. Heads up - the board is not easy to cut! Be patient and be careful to avoid cutting yourself.



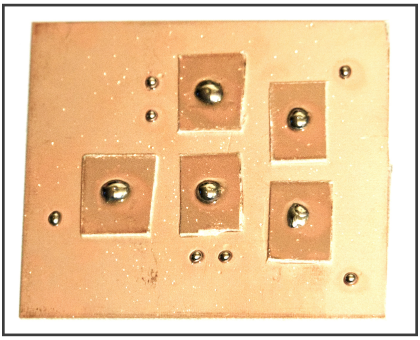
2. Take the strip and split it into 5 roughly even pieces, so you end up with six pieces that look something like this.



3. Affix the smaller pieces to the larger one as shown here, using the heat-resistant adhesive of your choice (we used gorilla glue in the board shown here, but other options work just as well).



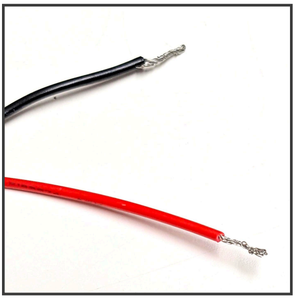
4. Create small solder pads on each of the smaller pieces of copper board by heating up the surface and applying solder until it forms a little pool. This will help to speed up soldering work later.

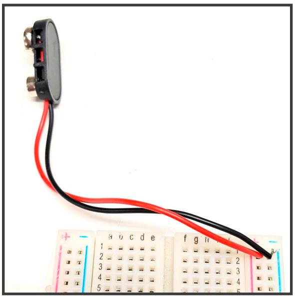


5. Using the same method as the previous step, create small solder pads on the larger copper board in the locations shown in the image to the left.

7.0
assembly instructions

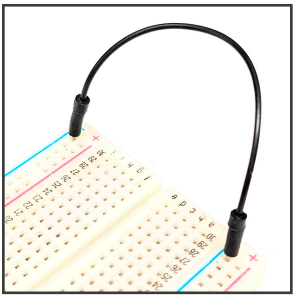
7.1 Breadboard Assembly





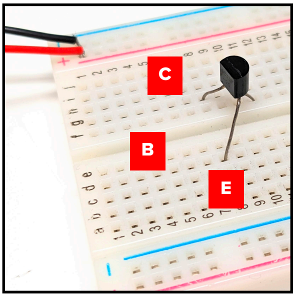
1. Attach the 9-volt battery connector to the board. These connectors often have stranded core wires. Twist the ends as tightly as possible before pushing them into the breadboard to ensure a good connection.

The wires will usually be insulated in black and red. Red indicates a "positive" lead and black indicates a "negative" lead. Push the black wire into a hole on the blue/negative rail on one end of the breadboard. Push the red wire into the a hole on the red/positive vertical rail immediately next to it. This configuration is not required, but it is a convention intended to help to keep track of the direction of current, in case you are working with more than one person or need to return to the board at a later time.

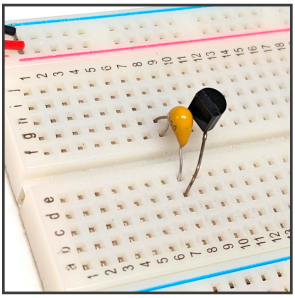


2. On the opposite end of the board from where you attached the battery connector, connect the two negative rails with a jumper wire. Push one end of the wire into a hole on one blue vertical rail and the other end of the wire into a hole

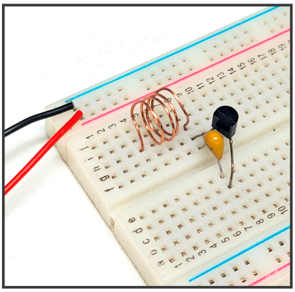
on the blue vertical rail on the other side of the board. This means that both rails share the same part of the electrical current.



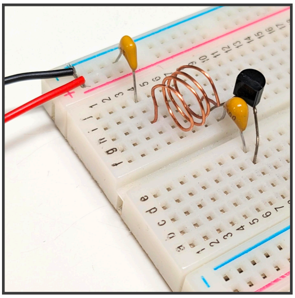
3. The transistor we are using has 3 legs: a Base, an Emitter, and a Collector. If you look at the transistor in this circuit with the flat side facing towards you, it has the Base (B) in the center, the Collector (C) on the left and the Emitter (E) on the right.Place the transistor so each of the legs are in a separate row, and the C leg is close to the positive rail. Leave room for another component to go between the C and E legs.



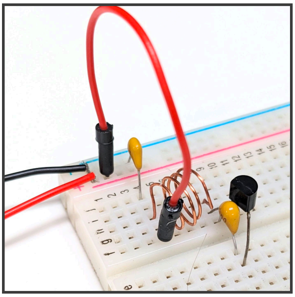
4. Place the 10pF ceramic capacitor (often marked "100") between the C and E legs of the transistor. Push each of the capacitor's legs into holes in the same rows as the C and E legs of the transistor.



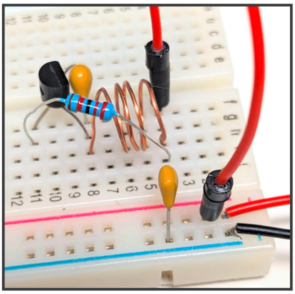
5. Place the coil you prepared earlier so that one leg is in the same row as the C leg of the transistor and the other is in a separate row. The C leg of the transistor is now connected to the coil electrically, because both are touching the same piece of metal under the surface of the breadboard.



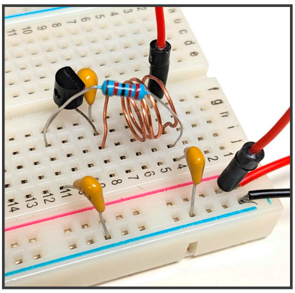
6. Use one of the 10nF ceramic capacitors (usually marked "103") to connect the coil end not connected to the transistor to the negative rail.



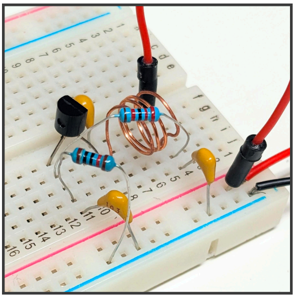
7. Use a jumper wire to connect the same row as in the previous step to the positive rail.



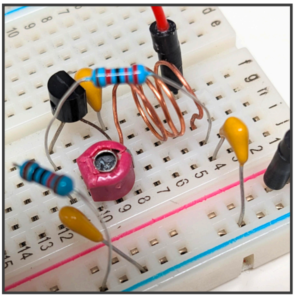
8. Use the 22 kΩ resistor to connect the row the same row as in the previous step to the row with the B leg of the transistor by inserting one leg of the capacitor in the same row as the B leg of the transistor and the other leg of the capacitor in the negative rail. (Note: this image shows the opposite angle from the previous image.)



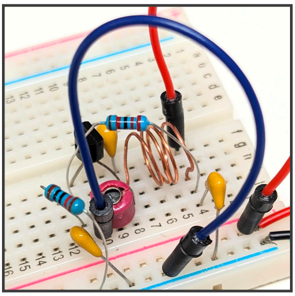
9. Use the other 10nF ceramic capacitor to connect the row with the B leg of the transistor to the negative rail, by inserting one leg of the capacitor in the same row as the B leg of the transistor and the other leg of the capacitor in the negative rail.



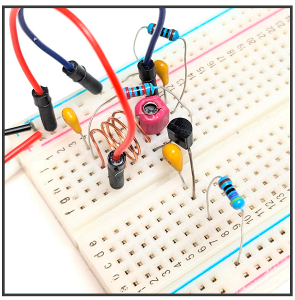
10. Use the 10 kΩ resistor to connect the row with the B leg of the transistor to the negative rail, by inserting one leg of the resistor in the same row as the B leg of the transistor and the other leg of the resistor in the negative rail.



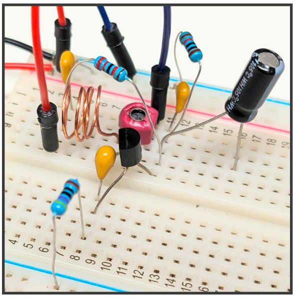
11. Carefully place the variable capacitor in the space between resistors, with one leg in the same row as the C leg of the transistor and the other leg in a row with no other components.



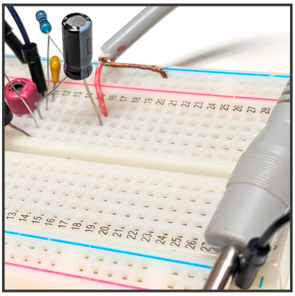
12. Use a jumper wire to connect the row with only one leg of the variable capacitor in it to the negative rail by inserting one end of the jumper wire in the same row as the variable capacitor and the other end of the jumper wire in the negative rail.



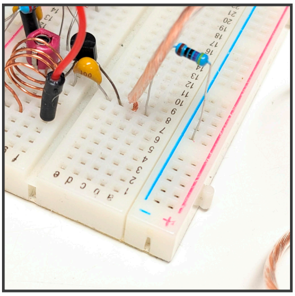
13. Use the 470 Ω resistor to connect the E leg of the transistor to the negative rail, by inserting one leg of the resistor in the same row as the E leg of the transistor and the other leg of the resistor in the negative rail. (Note: this image shows the opposite angle from the previous image.)



14. Insert the positive (longer) leg of the electrolytic capacitor in the same row as the B leg of the transistor. Insert the negative (shorter) leg in a row with no other components.

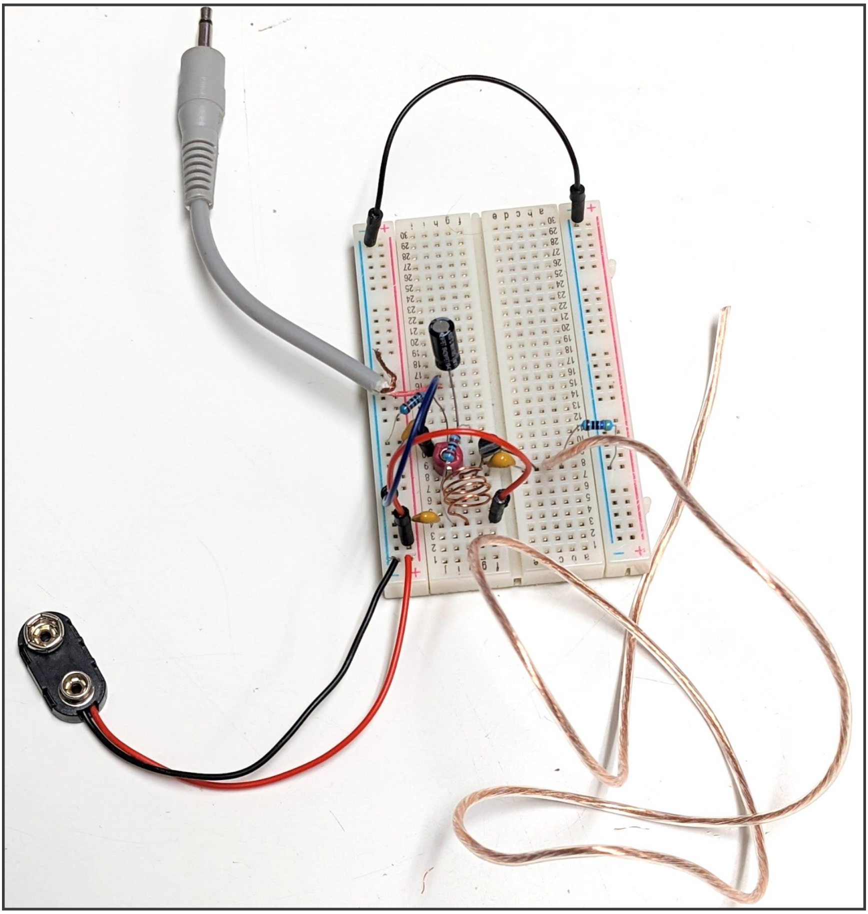


15. The mono audio jack will likely have stranded wires like the battery connector. Twist the strands in the same way. Insert the positive wire (usually insulated with red plastic - if it isn't, it will be the only insulated wire) in the same row as the negative leg of the electrolytic capacitor. Insert the negative wire of the audio jack (generally bare copper, not insulated) in the negative rail.

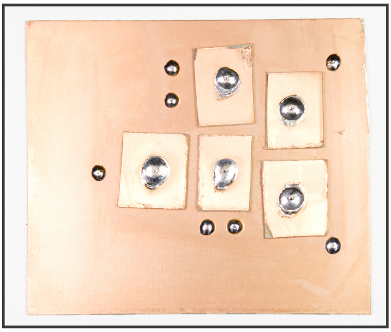


16. The antenna can be made of any type of wire, as long as it will fit in the holes in the breadboard. We've used a piece of stereo wire, but you could use a long jumper cable or other wire you have available. As always, if the wire is stranded make sure to twist the strands tightly. Insert the antenna wire in the same row as the E leg of the transistor.

17. The circuit should be fully assembled! Attach a 9v battery, and skip to "Operating the Completed Radio Transmitter" for your next steps!

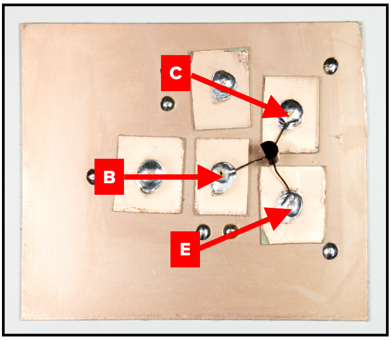


7.2 Soldered Assembly

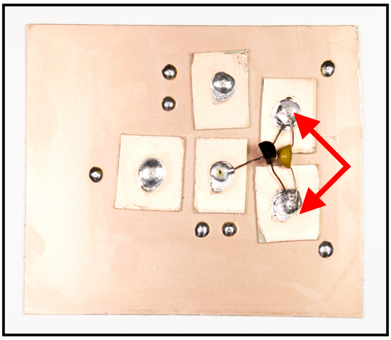


1.Begin with the copper-clad board you already prepared. You shouldn't need more solder than what is already pooled on the board. You will build the circuit by re-heating the solder and adding components to it.

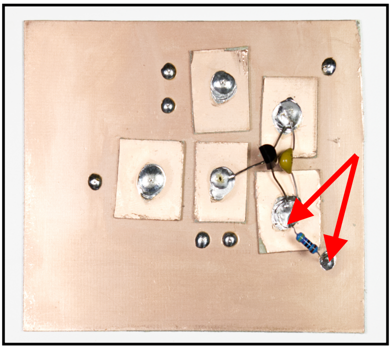
Going forward, the larger copper board is referred to as the "ground plate", and it will be connected to the negative terminal of the battery. The smaller pieces of copper board affixed to the surface of the ground plate are referred to as "insulated pads"; they are the connection points for components that lead to the positive terminal of the battery.



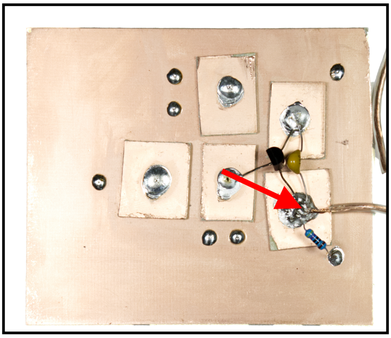
2. The transistor we are using has 3 legs: a Base, an Emitter, and a Collector. If you look at the transistor in this circuit with the flat side facing towards you, it has the Base (B) in the center, the Collector (C) on the left and the Emitter (E) on the right. Orient the transistor so that it matches the image here, with the B lead to the left, the C lead to the top right, and the E lead to the bottom right. Affix the transistor to the insulated pads by touching the leads to the solder pads and re-heating the solder with the soldering iron until it melts.



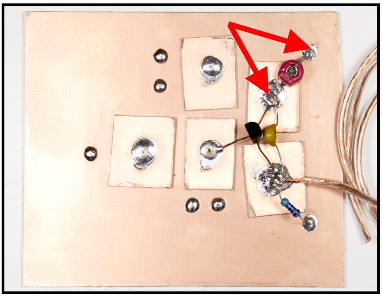
3. Next, attach the 10pF ceramic capacitor (usually marked with "100") so it connects the C and E leads of the transistor. Use the same method as before of reheating each pool of solder while touching the component leads to it.



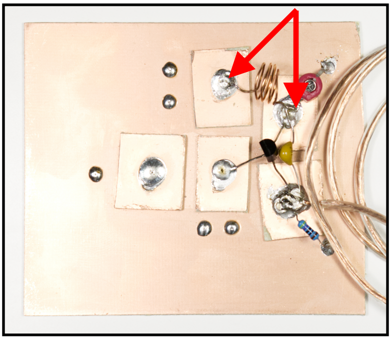
4. Using the same soldering method, affix one lead of the 470 Ω resistor to the same insulated pad as the E lead of the transistor. Connect the other lead of the 470 Ω resistor to the ground plate using the solder pad in the bottom right corner of the board.



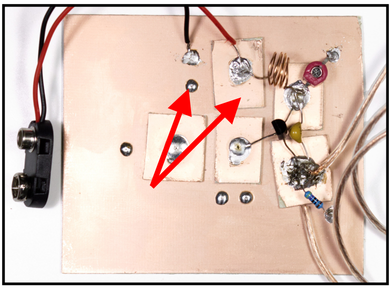
5. Use the wire strippers to remove a small amount of insulating plastic from one end of the antenna wire, exposing the copper strands. Continuing to use the same method, solder the exposed copper to the same insulated pad as the E lead of the transistor and leads of the 10pF ceramic capacitor and 470 Ω resistor.



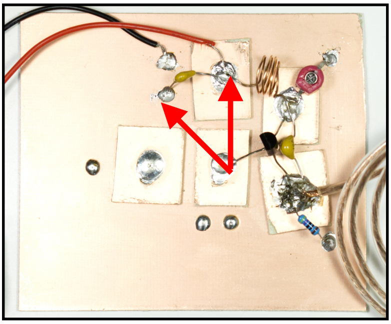
6. With the same soldering method, affix one leg of the variable capacitor to the top right insulated pad that already connects to the C lead of the transistor and one lead of the 10pF ceramic capacitor. Connect the other leg of the variable capacitor to the ground plate using the solder pad in the top right corner of the board.



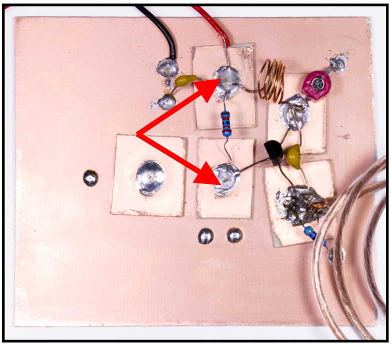
7. Using the same soldering technique, attach one end of the coil to the top right insulated pad that also connects to one lead of the variable capacitor, the C lead of the transistor, and one lead of the 10pF ceramic capacitor. Connect the other end of the coil to the insulated pad at the center top of the board.



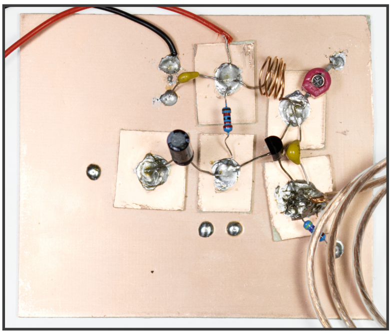
8. Use the wire strippers to remove some insulation on the wires attached to the battery connector. Using the same soldering method, attach the positive lead of the battery connector to the same center top insulated pad as the end of the coil. Affix the negative lead of the battery connector to the ground plate with the topmost solder pad.



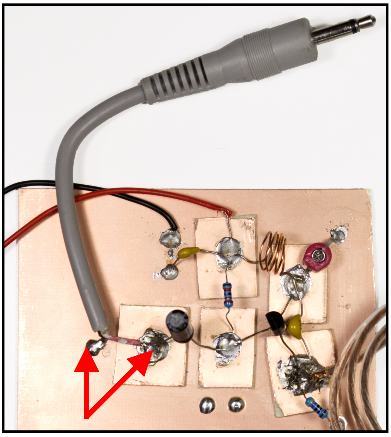
9. With the same soldering technique, affix one lead of one of the 10nF ceramic capacitors (usually marked "103") to the same center top insulated pad as the positive lead of the battery connector. Affix the other lead of the 10nF ceramic capacitor to the ground plate using the solder pad just below where you attached the negative lead of the battery connector in the previous step.



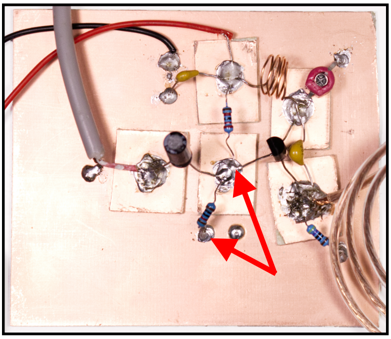
10. Solder one lead of the 22 kΩ resistor to the same center top insulated pad as the coil, 10nF ceramic capacitor, and battery connector in the previous 3 steps. Attach the other lead of the 22 kΩ resistor to the same center insulated pad as the B lead of the transistor.



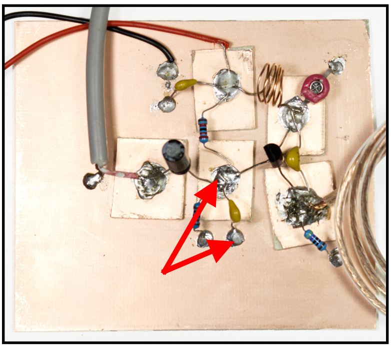
11. Use the same soldering technique to connect the positive lead (longer leg) of the electrolytic capacitor to same center insulated pad as the B lead of the transistor and one lead of the 22 kΩ resistor. Connect the electrolytic capacitor's negative lead to the insulated pad to the left.



12. Use the wire strippers to expose the audio jack wires. Connect the positive wire of the audio jack (usually insulated with red plastic) to the same left insulated pad as the negative leg of the electrolytic capacitor. Connect the negative wire of the audio jack (either bare copper or insulated with black plastic) to the ground plate using the solder pad to the left of that insulated pad.

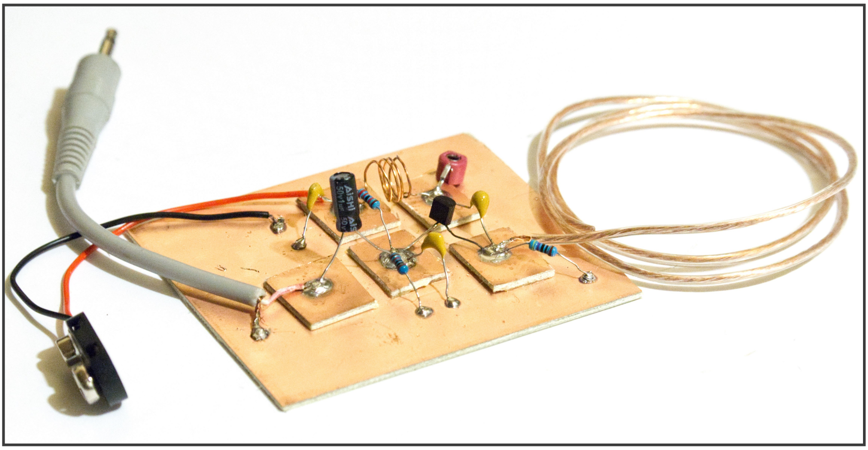


13. Use the same soldering method to connect one lead of the 10 kΩ resistor to the same center insulated pad as the positive lead of the electrolytic capacitor, the B lead of the transistor, and the lead of the 22 kΩ resistor. Attach the other lead of that resistor to the ground plate using one of the solder pads below that insulated pad.



14. Attach one lead of the remaining 10nF ceramic capacitors to the same insulated pad as in the previous step. Attach the other lead of that capacitor to the ground plate using the remaining solder pad.

15. The circuit should be fully assembled! Attach a 9v battery and continue on to "Operating the Completed Radio Transmitter" for your next steps!



7.3 Operating the Completed Radio Transmitter

Once you've built your radio transmitter, operate it by following these steps:

1. Connect a 9 volt battery to the battery connector and connect an audio source (such as a phone or computer) to the audio connector.

2. Turn your audio source to the highest volume and play something you will recognize.

3. You can find the audio you chose in step 2 in two ways:

    3.1. Turn on an FM radio receiver, and slowly scan through the stations until you find the audio. While this process of scanning works best with a radio that has a knob for tuning, a digitally-tuned radio will also work. With this method you leave the transmission frequency of your radio transmitter as-is and you adjust the reception frequency of the receiver.

    3.2. Set your radio receiver to an empty channel at the low end of the FM spectrum (87.1-90.9, generally) and use a small screwdriver to carefully turn the screw head inside the variable capacitor on your transmitter. With this method you adjust the transmission frequency of your radio transmitter.

4. Once you've found your audio, play around with both methods to find the best sound! You can experiment with how far apart the transmitter and receiver can be, what causes interference, what increases your signal strength, etc.

7.4 Troubleshooting

1. If you are having trouble picking up your radio frequency, or it seems to not be working, try the following things:

2. Go through the steps of your assembly method and double-check that each component is connected in the correct place and orientation.

3. If you assembled your circuit on a breadboard, lightly sand the leads on each component. There may be transparent insulation on the leads that is preventing electricity from moving through the circuit.

4. If you assembled your circuit by soldering, carefully reheat each of the solder joints to make sure that solder has connected each of the components.

5. Make sure that all batteries have a full charge.

6. Check that your radio is receiving other frequencies by scanning for local radio stations.

8.0 acknowledgements

This text is an expansion of work done by Tetsuo Kogawa. The instructions expand on his Simplest FM Transmitter (anarchy.translocal.jp/radio/micro/howtosimplestTX.html) and the circuit diagram is based on a layout for the BC337 transistor-based circuit (translocal.jp/radio/micro/simplestTX__layout__for__BC337.pdf).

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9.0 bios

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